



Insulation Error in PV Systems

1 Content

Insulation errors occurring during operation in PV systems with transformerless inverters can lead to severe errors or even the destruction of the inverter. It must therefore be ensured that no PV strings with defective insulation are connected or will be connected to a transformerless inverter.

The information in this document is intended for installers and operators of PV systems with SMA inverters. The corrective measures described in this document may only be carried out by qualified persons.

2 Protective function of the inverter

Insulation resistance measurement before connecting to the utility grid:

SMA inverters are equipped with a protective device to detect insulation errors on the DC side. The protective device measures the insulation resistance of the connected PV string before the inverter connects to the utility grid. If the measured values are above the specified limit, the inverter connects to the utility grid and becomes ready for feed-in operation. If the measured values fall below the minimum insulation resistance threshold, the inverter will display a corresponding error message and will not connect to the utility grid. A low insulation resistance is indicated by event message 3501.

3 Inverter response to a ground fault during operation

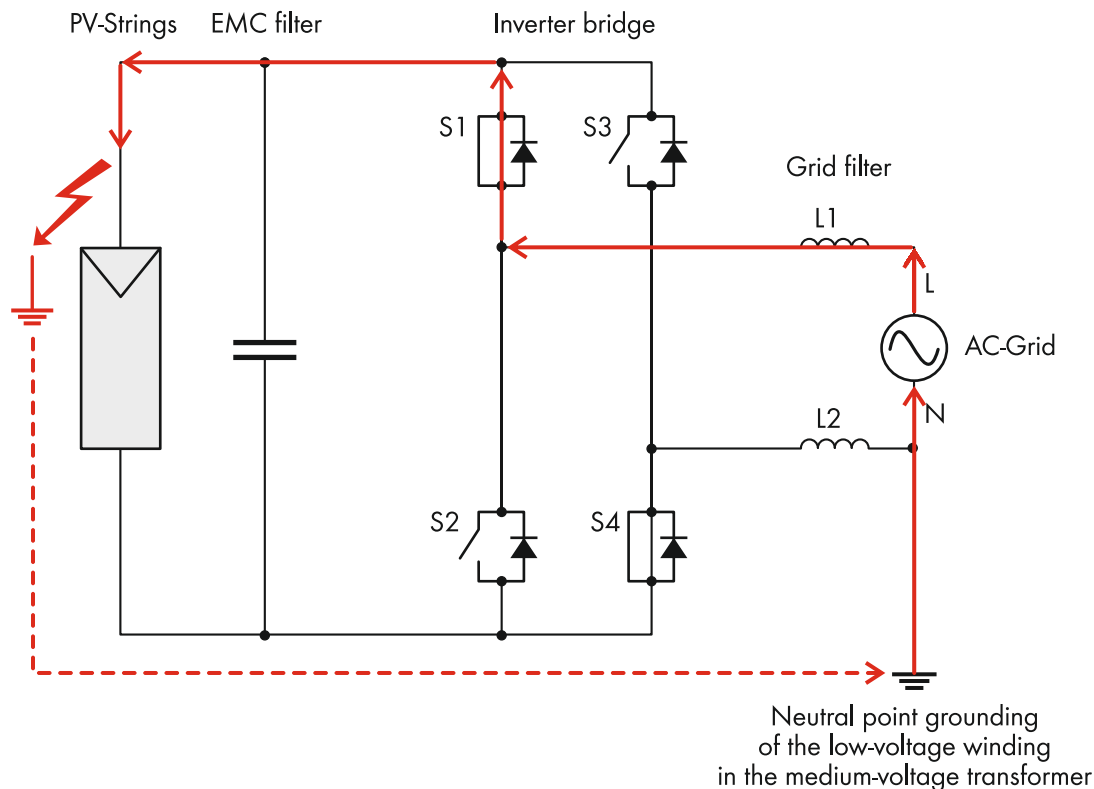
What happens if a ground fault occurs in the connected PV strings during the inverter's feed-in operation?

Transformerless inverters lack galvanic isolation between the installation's DC circuit (connected PV strings) and its AC circuit (connected to the utility grid).

If a fault occurs, the current driven from the AC grid side through the inverter's grid bridge can far exceed the permitted current limits for the affected components, particularly damaging the power modules (IGBTs) or the grid disconnection point (relay).

In principle, the inverter can detect a ground fault during operation via its integrated residual current monitoring system and can initiate the disconnection of the grid relays. In the event of a fault, however, the grid disconnection cannot occur quickly enough to prevent damage to the inverter components, as the speed and magnitude of the current rise far exceed the typical limits of the affected components. The inverter and its components meet all standard requirements, which means that any damage caused by a ground fault during operation is not considered a fault of the inverter. This error is therefore not covered by the warranty.

The following figure shows the equivalent circuit diagram of an inverter stage, providing a simplified representation of the current path in the event of a ground fault in the connected module field:



In the event of a failure, the current flowing through the connected utility grid can exceed 1 kA. The magnitude of the resulting current depends on the AC grid voltage. If a ground fault occurs at the peak line voltage, the rise in residual current is so rapid that the inverter can no longer disconnect from the utility grid without sustaining damage. If the fault occurs during the natural zero-crossing of the grid voltage, the residual current increases more slowly, and under certain circumstances, the inverter can disconnect in time without sustaining damage.

4 What damage can occur as a result of a ground fault during operation?

The damage to the inverter's components can be varied and therefore cannot be represented by a single, specific pattern. The event messages listed below may occur as a consequence:

- Event 64xx
- Event 77xx
- All LEDs are off

The inverter's event messages can be found in the system logbook or event monitor in Sunny Portal powered by ennexOS. Alternatively, you can retrieve the event messages from the inverter's user interface (see inverter manual). In case the inverter displays event messages related to insulation errors (event 3501 / 3502 / 3503) or leakage/residual currents (event 3601 / 3701), we strongly recommend having the PV system inspected by a qualified person to identify any potential errors or weaknesses. Since insulation errors can also occur sporadically, for example, due to climatic influences, such as storm damage, dew, or rain in the case of defective cable insulation and/or plug connections, it is not always easy to detect them. However, a thorough system inspection remains essential.

5 Event 3501

QUALIFIED PERSON

Event message:

- **Insulation failure**
- **Check generator**

Explanation:

The insulation resistance of the DC installation is or was too low. The inverter disconnects from the utility grid for safety reasons and/or fails to connect during self-test mode. The cause is often defective insulation or a faulty plug connection on the PV modules or within the DC wiring. The event message can occur temporarily as it is influenced by ambient conditions such as rain or dew. In addition, mechanical influences (e.g. strong wind) can cause live DC cables to come into contact with grounded system parts if the cable insulation is defective. Inverters without a transformer can be destroyed by an ground fault during operation.

Corrective measures:

- Check the frequency and duration of the event message in the inverter's user interface or in the Sunny Portal. The measurements listed below should be performed under the same ambient conditions and at the same time of day as when the error occurred—ideally while an event message is active.
- If module electronic components, such as SunSpec-compatible module disconnectors, are present, an additional device is required to maintain the SunSpec PLC signal.
- Verify through measurement of the open-circuit voltage of the PV strings that the measured values correspond to the system design and prevailing irradiation conditions.
- Measure the voltage of each PV string between DC+ and PE, and between DC– and PE, using a suitable measuring device. If a stable voltage is measured that approximately equals the string voltage, this indicates a ground fault. Correct the ground fault on the relevant PV string and only then reconnect.
- Measure the insulation resistance of each PV string using an insulation resistance meter. Ensure that the PV string is short-circuited during these measurements and that the maximum permissible system voltage of the PV modules is not exceeded. If the insulation resistance is too low, it indicates a ground fault. Correct the ground fault on the relevant PV string and only then reconnect.
- Visually inspect the entire DC installation (PV modules, cables, plug connections, and any existing components such as module optimizers or disconnectors) to ensure there are no signs of damage, such as porosity, cracks, crushing, deformation, or discoloration. Replace or repair any defective components.

Tip: Use an IR camera for support.